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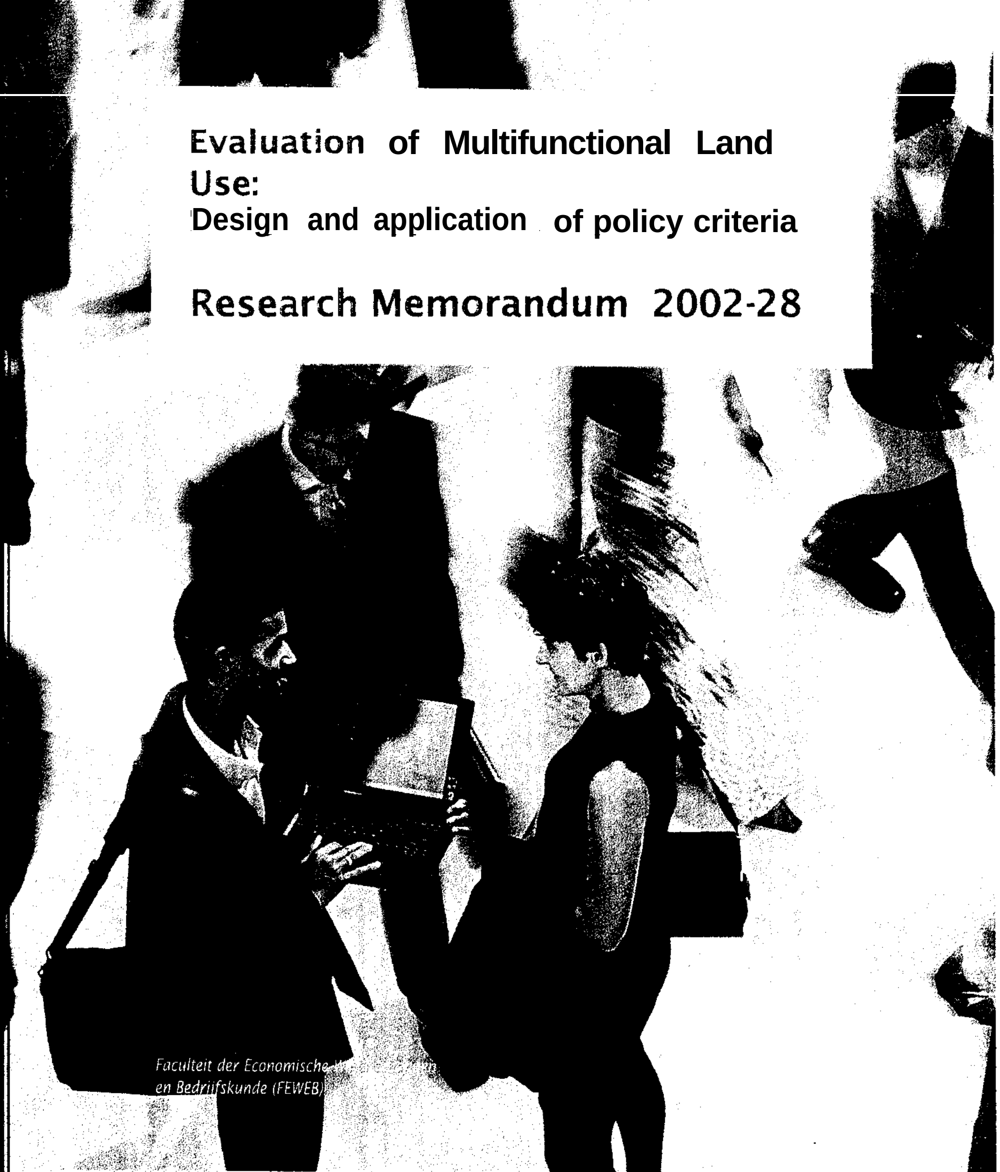

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Evaluation of Multifunctional Land Use:
Design and application of policy criteria

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EVALUATION OF MULTIFUNCTIONAL LAND USE: DESIGN AND APPLICATION OF POLICY CRITERIA

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Abstract
Multifunctional land use has recently received increasing attention, both es a planning concept and as a tool for integrated modelling. When e multifunctional spatial planning design is used, socio-economie synergy benefits may be obtained, if several (complementary or mutually strengthening) functions are exercised at the same place and time. The present paper aims to offer a new contribution to the economics of multifunctional land use by analysing this concept in greater detail from an operational end integrative perspective. A functional typology of specific land use functions is presented, along with the development of assessment criteria to measure the degree of multifunctionality of specific land use projects. A Dutch case study of a multifunctional land use project, the so-called Amsterdam South-Axis, is presented and analysed as an illustrative case.

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1. Introduction

The economic science has traditionally put great interest in land use. This interest sterns from three characteristics of land: i) land is scarce, ii) land has altemative use options, and iii) land has a social value in the economy. Economists have typically focussed on questions of efficiency and (more recently) sustainability of land use. These studies are generally concemed with 'monofunctional' land use pattems. Since recently, however, also the concept of multifunctional land use has gained interest. Multifunctional land use attempts to combine several socio-economie functions in the same area, so as to conserve scarce space and to exploit economies of synergy. The aforementioned characteristics of land use can also be used to study the concept of multifunctional land use from a socio-economic perspective. The present paper aims to analyse the concept of multifunctional land use in greater detail by focussing on specific land use functions and by analysing the opportunities for benefiting from multifunctionality in designated land use projects. Therefore, in Section 2 a set of different land use functions is defined, along with the relationships between them. Since this paper focuses mainly on urban areas, not all land use functions will be taken into account. This paper concentrates mainly on multifunctional land use projects that include, at the very least, an infrastructure function. Definitions of the most important concepts dealt with in this paper (land use, infrastructure and multifunctionality) are presented in Section 3. Before the relationship between these concepts is analysed, the factors that determine urban land use are examined (Section 4). These are investigated from a multifunctional point of view as well. Section 5 then provides a theoretical overview of the relationship between land use, infrastructure and the multifunctional organisation of space, as it relates to possibilities for the emergence of synergy effects. These analytical contributions form the basis for the indicators framework presented in Section 6, through which multifunctional land use projects may be quantitatively analysed in terms of the degree of multifunctionality. Section 7 is an initial attempt to explore a multifunctional land use project (the so-called South-Axis ('Zuid-as') in Amsterdam). Section 6 offers some concluding remarks.

2. Identification of land use functions

An empirical analysis of multifunctional land use of course requires unambiguous definitions of its elements; i.e., of the different land use functions to be distinguished. Our study will distinguish nine such (rather aggregate) functions (Rodenburg, 2001), namely:

Residential housing is defined as the space that is used for (permanent) living.
Work end business refers to the space that is used for commerce and industry. This includes, for example, office locations and industry locations.
Amenities include non-profit organisations (hospitals, schools, museums, churches, etc.) as well as shopping facilities.
Infrastructure refers to the space (including safety buffers) that is used to facilitate movement of goods and persons. This includes the transport infrastructure (roads, railways, waterways, terminals, ports, and airports), the communication infrastructure (data-communication networks), energy facilities (electricity network) and the water infrastructure (dikes, bridges, locks, sea walls, etc.).
Recreation and culture has a broad definition. Benches along public roads are not included. Areas included are day trip destinations, campgrounds and amusement parks. Space consumed by cultural functions is also included.
Water refers to the space taken up by rivers, watercourses, lakes and territoria1 waters that have a 'water management' function. This also includes areas that have a drinking water function, e.g. storage of drinking water, and filtration areas.
Agriculture refers to the space that is used for cropland, pasture, orchards, vineyards, and horticulture, but also to the space needed for intensive, non land-wnstricted cattle breeding.
Nature end landscape means, in its broad definition, the space needed to maintain or guarantee the current quality of nature (biodiversity). In its narrower definition, it may refer to the Main Ecological Structure: a policy concept used in the Netherlands to indicate a spatially wnnected network of larger units of nature (including water). The broad definition will be used here.
Remaining includes the use of land that cannot be classified under one of the land use functions as described above.

These individual spatial functions are defined to be mutually exclusive. This means that the sum of the total tand area cannot ba exceeded by the sum of the tand area consumed by the different functions. The initial starting point is therefore a monofunctional land use situation in which each type of land use has its own characteristics of demand and supply.
Figure 1 shows the relations between the various functions (except for the function 'remaining land') and the external forces that affect the system of land use and vice versa. Examples of external forces are the actual spatial organisation, as well as demographic and geographic influences. The highlighted part shows the focus of this paper: the transport function and the land use functions most directly related to it in a multifunctional context. Remaining land is not included in this figure since there are no direct relations to be indicated between remaining land and other functions. This will ba dependent on the activities exercised on the remaining land.

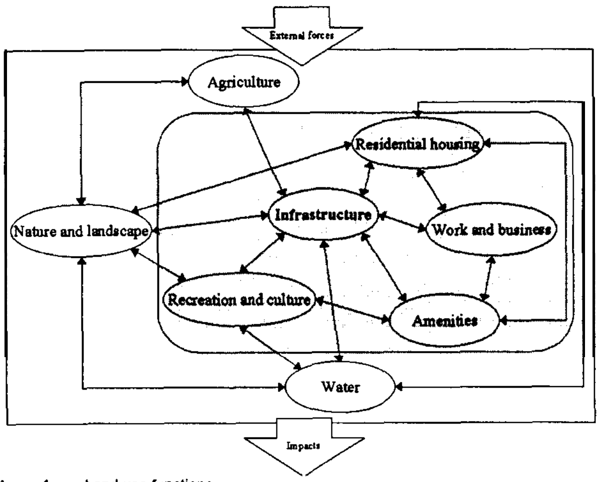

Figure 1 Land use functions

A few remarks should be made. First, time is an important aspect of this figure for two reasons. 1) The arrows all point in two directions, but this does not necessarily mean that both influences take place at the same time. For example, the influence of residential housing on amenities is direct, since people want shops, schools, etc., close to their homes, but the development of a big shopping centre does not necessarily mean that houses will soon be established near it. 2) Also, more generally, different arrows may refer to different time spans. For example, infrastructure has an influence on all other functions, but not necessarily at the same moment. Second, it is very well possible that certain relationships are more likely to occur than others are.
Urban spatial structure consists of the layout of the physical components of an urban area and their interrelationships. These are continually evolving, so that spatial structure is a dynamic phenomenon, changing over time and in space (Dowall, 1978). In determining urban structures and location behaviour, the land use system and the transportation system (regarded here as the system of transport infrastructure) are highty interdependent. Briefly stated, location decisions made as a result of land use activities are, to a large extent, the result of the relative cost of travel to various opportunities. Given the structure (layout, capacity, geographical position, etc.) of the transportation system, the pattern of trips generated by these activities affects the costs of travel in the region. It can be said, therefore. that the spatial organisation of land use determines and, at the same time, is determined by, the design and characteristics of the transportation system. It is interesting to analyse this dual relation in greater detail, especially in light of multifunctional land use.

3. Definition of land use concepts

Before diswssing the dual relation between land use and transport infrastructure, it is important to determine the main concepts that will be dealt with in this paper: land use, multiiunctional land use, and infrastructure. as well as factors determining land use decisions. The latter category will be discussed in Section 4.

Land use generally refers *to* "how land is put to use' (Chapin and Kaiser, 1979). As has been explained in Section 2, nine different land use functions are distinguished here, one of which is infrastructure. When multiple functions emerge at the same location, there is a shift from monofunctional land use to ***multifunctional** land* use. To define multifunctional land use adequately. it is important to identify its time dimensions and its geographical scale levels. The longer the time-span the greater the extent of multifunctional land use. The larger the scope of the geographical scale, the greater the extent of multifunctional land use.

There are several current definitions of multifunctional land use. That of Lagendijk and Wisserhof (1999) is the most commonly used. It states that one can speak of multifunctional land use if at least one of the following four conditions are satisfied: (1) intensification of land use (an increase in the efficiency of the land use for a function); (2) intetweaving of land use (use of the same area for several functions); (3) using the third dimension of the land (the underground along with the surface area), and (4) using the fourth dimension of the land (use of the same area for several functions within a certain time-frame). However, there are some remarks to be made that mainly concern the first element of the definition. In comparison with the other elements, intensification is a process, whereas the other three elements represent a state. This means that intensification itself cannot be observed in a static sense, but only in relation to developments over time or between different land use alternatives. Interweaving as well as the use of the third and fourth dimension can be obsewed as being present or not, at a certain moment. Furthermore, intensification may strictly spoken be also a matter of monofunctional land use. Only above a certain scale level intensification can lead to multiiunctional land use. since more land becomes available for other functions. The interweaving of land use is defined by 'use of the same area for several functions'. but it is preferable to call this 'diversity'. Intenveaving, then, can be seen as the degree in which different functions touch upon other functions. For example, within a project area of 400 m^2, four different functions of 100 m^2 each may be less interwoven than the same number of functions having in total 100m^2 per function as well, but scattered over the project area.

The combination of different land use functions at one location means that the land use intensity increases. Since in many countries the intensity of land use has increased in the last decades and will probably increase further, it is difficult to develop a clear definition of multifunctional land use. The concept of multifunctional land use is very broad. It can range from a combination of two economic functions to the combination of all nine economic functions shown in Figure 1, depending on the chosen scale level. In this paper, the project level has been chosen as the scale level. The boundaries of the project define the area that will be analysed. When seen from a project perspective, it is very hard to indicate whether projects are multiinctional or not. They can only be considered more multifunctional or less multifunctional. Therefore, a *more* suitable definition of multifunctional land use in a dynamic context would be:

A land use pattem is said to bewme more multifunctional when the average number of functions and/or units of land increases in the area considered. An increased degree of multifunctionality may therefore result from the addition of functions to the area (multifunctionality by diversity) or from a decrease in the average size of monofunctional areas (multifunctionality by interweaving).

Increased multifunctionality may be the result of market forces, government policies, or both. From an ewnomic perspective, market forces can be subdivided into demand factors (such as an increased preference for diversity of products and services and marketing externalities) and supply factors (such as agglomeration externalities).

It is important to identify specific focal points in order to design an operational definition of multllunctional land use in actual situations (case studies). Nijkamp et al. (2000a) have carried out an electronic interactive consultation about the definition of multifunctional land use. The consultation made clear that when applying the definition of multifunctional land use to actual situations. the time dimension and geographical scale level must be specified, but also the following aspects need explicit consideration:

1. The *efficiency* of the multifunctional land use project, compared to the current use of the land, not only as far as the costs of space and space-saving are concemed, but especially, as far as quality of space and sustainability are concemed;
2. The *diversity* of the project's appearance: this can be an extension, such as a new development, or an intensification, which means a change in the organisation of space;
3. The *synergy* of the economic and spatial functions that are brought together. leading to increasing returns to scale.

The third specific concept that will be focussed on in the context of this paper is infrastructure. Infrastructure is a very broad concept that will not be dealt with in full detail in this paper. A general description will be given first, after which we will focus on certain areas. To define the concept of infrastructure turns out to be more problematic than one might initially think. Definitions often consist of partial descriptions or enumerations of elements summarised by the author under the heading of infrastructure. One of the efforts to coma to an integral definition of infrastructure can be found in Nijkamp et al. (2000b) where infrastructure is defined as follows (translated from Dutch): *'infrastructure contains those immovable services that increase the efficiency of the use of production factors and that fulfil the following conditions: infrastructure is directly pmductive, is chamctedsed by a stock chamcter (capital good) and has the chamcter of a (semi) public good'.*

Nijkamp et al. define three categories of infrastructure: physical network infrastructure, immaterial knowledge infrastructure and natural and environmental infrastructure. The physical network infrastructure fulfils the following conditions: it has, to a large extent, a network character. is largely non-substitutable, and is, to a large extent, location-bounded and polyvalent. It is related to transport, public utilities, water management, and industry locations. Since the other two categories fall outside the scope of this paper, they will not be discussed hare. This paper addresses transport infrastructure. In the spatial interaction behveen different economic activities, transport plays an important role. Transport infrastructure facilitates the movement of people and goods, as well as the provision and distribution of services. Transport infrastructure therefore fulfils one of the most important spatial functions; transport is one of the most pervasive activities in any society or economy (Hoyle and Knowles, 1992). The definition of transport infrastructure that will be used in this paper is as follows: all infrastructure present in the case-study area that serves the physical movement of people and/or goods.

Transport infrastructure typically is not supplied through the market mechanism. It then may become unclear whether demand for and supply of infrastructure are harmonised. If it is assumed that infrastructure development follows demand, norms can be set that infrastructure has to fulfil. In this case, infrastructure follows economic and demographic developments, complementlng them. Conversely, infrastructure can steer or initiate ewnomic development. Investment in infrastructure can lead to an increase in productivity and to the creation and relocation of employment and other activities.

4. Factor0 determlnlng land use decisions

The most important concepts in this paper were defined in the previous section: now it is important to analyse why and how the concept of multifunctional land use originated. To understand land use decisions, we must consider the factors determining profitability and utility. Five main factors can be identified (based on Harvey, 2000): *accessibility, agglomeration economies, historica/ development, topographical features,* and *technological development.*

. *Accessibility* can be defined as 'the money. time and trouble costs of getting anywhere' (Harvey, 2000), where accessibility increases if these costs decrease. Firms require accessibility to factors of production (especially labour) and to markets. Households, on the other hand, require accessibility to work opportunities, shops, schools and recreational facilities. Accessibility is largely dependent upon transport facilities; transport costs are therefore an important determinant of the locations of firms and households. Other determinants are the money, time and trouble costs of travel as well as wmmunication costs. These costs result from the fact that spatial interaction - in a general sense - involves the movement of people, goods, production factors or services, or the transfer of ideas and information.

- *Agglomeration* economies, in the broadest sense, may also influence location decisions. This means, for example, that by locating closer together, firms can produce at lower cost. In agglomeration economies, activities compete for scarce space. There are various types of agglomeration economies, such as localisation economies, urbanisation economies and shopping externalities (e.g. O'Sullivan, 2000). To create localisation economies, firms locate themselves close to other firms in the industry, clustering in order to decrease their production costs. Urbanisation economies occur if the production cost of an indlvidual firm decreases as the total output of the urban area increases. Shopping externalities arise if shops selling comparable goods profit from their mutual proximity by offering consumers greater choica and improving the location's reputation as a source for a particular good.
- *Historical development:* current and future development is often dependent on past development and on the current function of an area. At some geographical locations, land use patterns may be heavily influenced by location decisions made by the Romans or by nineteenth-century industrialists; other land use patterns are clearly the product of twentieth-century planning. This path dependency means that present spatial organisation is a logical starting point for an analysis of the future land use of certain areas.
- *Topographical* features: geographical heterogeneity is an important factor in the location decisions for certain activities. An activity's ultimate location is often dependent on physical features such as rivers, mountains, plains, slopes, wind, climate and geology.
- *Technological developments*, together with increases in real income, are important factors that determine land use decisions. The widespread ownership of cars and freezers, together with new retailing techniques, largely accounts for the setting-up of out-of-town hypermarkets, retail warehouses and shopping centres. The development of road transport has also resulted in the construction of residences on the land between the major transport routes of urban areas and in the movement of households towards the peripheries. For offices, the effects of technological development are mixed. New building techniques have reduced the cost of upward building, leading to more intensive development of the CBD. Improved information technology. in contrast, enables the majority of office procedures to be carried out at sub-centres.

The aforementioned factors influencing ultimate land use decisions can also be used to explain the increasing attention now being paid to multiiunctional land use.
If different land use functions are combined, *accessibility* becomes even more important. In every urban area there are locations where the transport routes and systems converge. These locations are the positions with the greatest accessibility for the population of the urban area (Lean, 1969) and are therefore very suitable for multifunctional land use. At these locations, transport costs are lower (shorter distances, but also multipurpose trips), enabling firms and households to save time and money on transport. Concerning the *agglomeration economies.* their number could increase with an increase in multifunctional land use. Urbanisation economies and shopping externalities are particularly likely to result kom multiiunctional land use. Obviously, *historica/ development* and *topographical features* do not change as a result of the combination of functions in space.
The final factor, *technological development* is an important reason for the development of the concept of multifunctional land use. Not only improvements in construction techniques, but also developments in ICT possibilities have created new insights into opportunities for combining economic activities.

Another important element must be taken into account conceming location dectsions and multifunctional land use: *scarcity of land.* The scarctty of land is an important reason for the develppment of multifunctional land use. People do not want only to live in densely populated areas, but also want to be able to work, shop, move around, etc. in order to maximise their utility. If all these different activities have to be carrled out in a limited space, land use functions will have to be combined (e.g., by using the third and/or fourth dimension). This type of development corresponds with one of the main charactertstics of the urban economy; the interdependenca of land uses, which is largely created by external economies and diseconomies of production and consumption. These interdependencies bring about entirely different uses and values in areas with the same level of general accessibility. The theories on the concentrtc ring pattem of the spatial distribution of land use and the smooth pattem of the rent gradient may, therefore, have to be modifted. The spatial distribution of land use patterns can be expected to bewme far more patchy as complementary land use patterns are gathered together in specific parts of the city where they can more easily enjoy the benefits of their proximity. The rent gradient will consequently show "bumps"; temporary rises in land values reflecting areas of land use where neighbourhood economies are very favourable (Newell. 1977).

5. *Relation between land use, infrastructure and the multifunctional organisation of space*

Different relationships between land use and transport infrastructure can be identifted. The pattern of influence is mutual: land use influences transport infrastructure, since general spatial and land use patterns have an impact on transport volumes; and transport infrastructure influences land use, since transport infrastructure has certain spatial/land use requirements. This relation is dynamic and ongoing, as is illustrated in Figure 2. The figure shows that basic forces, such as demography, historica1 developments, geographical location, soil conditions and economic development, form the basis for decisions about land use. Once the land use pattern has been determined, transport infrastructure must be developed to enable the transport of persons and goods to the area (*t*). Transport infrastructure can also provide access to new areas, thereby enabling land use patterns to change (*t+1*). Once established, however, land use pattems largely determine demand for transport.

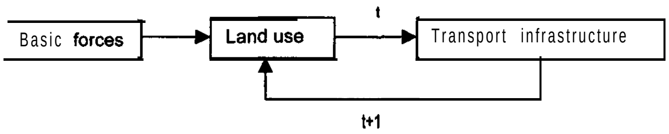

Figure 2 **Dynamic relations** in the land **use** – transport system

As early as in the classica1 economic theories on land use, a relation between transport and tand use was identified. The role of transport infrastructure is, directly or indirectly, present in traditional economic growth theories. An example is the location theory, which shows that changes in infrastructure networks lead to changes in the spatial organisation of activities (Bruinsma, 1994).
Transport infrastructure influences spatial organisation in various ways, but its major influence on regional economies is that it enables specialisation. A simplified example can serve as an illustration (Taaffe and Gauthier, 1973). If there is little or no transportation as a result of a lack of infrastructure, cities are isolated from each other (Figure 3a). Each individual city (X and Y) produces a range of products dependent upon its own consumption needs. X might, for example, have the best conditions to grow product 1, but the amount of land used for the production of product 1 will depend upon the amount of product 1 consumed by the inhabitants of city X. The same might hold true for city Y for product 2. If transport opportunities arise when a road is constructed between X and Y (Figure 3b), the first signs of specialisation will appear; X will expand its production of product 1, whereas Y will expand its production of product 2. Each city will transport its surpluses to the other. For city Y, the costs of transporting product 1 into its area are lower than the costs of producing product 1.

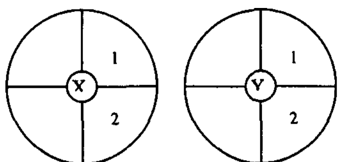

Figure 3a **Isolated** cities without infrastructure

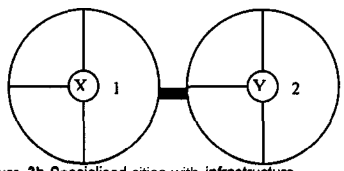

Figure 3b Specialised cities with **infrastructure**

This example shows the importance of transport infrastrudure to regions. The same logic can also be applied to the determination of land use functions. Different land use functions cannot exist in an isolated state in the way that cities can. Different functions always need transport infrastructure between them, since, for example, a residential housing function can not be economically self-sufficient without a place to grow crops and the opportunity for its inhabitants to buy food. If different land use functions are combined in space, infrastructure is still important, since not all land use functions can be combined in an economically efficient way. A certain combination of functions will most likely generate high revenues, but it is clear that there will always remain scattered functions without synergy. The latter must be made accessible via the transport infrastructure. In other words, only those combinations of functions that are expected to have synergy (or at least no dis-synergy) effects will occur.

Transport costs form an important element of the relation between land use and infrastructure. A substantial part of the interaction among urban activities takes place via the urban transportation system. This system can also create changes through the imposition of its costs on its users and on the wmmunity at large. A distinction must be made between public and private costs. Public costs consist of the expenditure of funds by public bodies for the wnstruction, operation and maintenance of transportation facilities, whereas private costs are mainly out-of-pocket money and time costs to individuals. Public costs result from and affect community decisions about how the transport system should perform as a whole. Private costs, on the other hand, result from and affect the trip-making and locating behaviour of persons. Together, these costs have a huge impact on the spatial organisation of an urban region, since public investment in infrastructure tends to reduce the private time or money costs of movement. If these costs are reduced, the wsts of economic linkages of the movement of goods and persons will also be reduced (Wingo, 1963).

The effect of infrastructure on spatial patterns of economic activities is especially important in areas with high land use intensity, where there is multifunctional land use. The spatial needs of transport infrastructure might conflict with, for example, habitats, archaeological sites, cultural and historica1 sites, agricultural areas, recreational areas or settlements. Transport infrastructure consumes land directly (e.g. roads, rail stations) as well as indirectly (mainly by causing spatial development). The extent of the space needed depends on the mode of transport and on the speed of travel (ELTIS, 2002).
Integrating the planning of transport, infrastructure, and urban and regional policies can help to reduce the need for travel and can decrease emissions. land use, and resource wnsumption. For sustainable development. strategic integratlve planning, which involves impact assessment (i.e. the application of strategic environmental assessment), helps to create land use patterns that place activities close to each other, thereby reducing the need for travel between them. Planning should emphasise accessibility rather than mobility. i.e. the aim of planning should be to enable everyday activities to be carried out with less travel. A pattern of smaller urban areas is probably not suitable for attaining this goal, since they generate more traffic than compact centralised cities. On average, throughout the EU, travel demand falls if population densities are greater than 50 inhabitants/hectare (European Environment Agency, 1995). Multifunctional land use could be used as an instrument to decrease demand for travel, when it increases population density. One could say that the current congestion of major roads is a negative development that encourages multifunctional land use and multifunctional time use, whereas technological factors (including ICT) are a positive development that enwurages multifunctional land use and multifunctional time use (Priemus et al., 2000). Changes in the time and space budgets of individuals and households play an important role in this process.

6. Framework for analysis

The observations so far form the basis of a framework for the analysis of multifunctional land use projects. The analysis attempts to identify criteria that measure the degree of multifunctionality of a certain land use project. There are various publications about all kinds of criteria and indicators to measure, for example, specialisation, diversity, and intensification (see, e.g., Harts et al. (1999), Piepers (2001), McCann (2001), and Fouchier (1996)). However, the criteria used in this paper do not have to be assigned only to the different land use functions, but have to be also adjusted for the scope of a specific multifunctional project. The adjustment of criteria will mainly be dependent on the specific land use functions involved in the muitifunctional project wncemed.

Operational indicators to measure the degree of multifunctionality of a certain land use project have to be related to the elements of the definition of multiiunctional land use as presented in Section 3. As a starting point, it is important to define what we want to measure, or, in other words, from which viewpoint we want to reason. A logical starting point is the creation of a distinction between input and output (performance) of land use. Since this paper deals mainly with the supply side of land use, our starting point will be the input side.

A first multifunctionalii indicator that complies with the definition of multifunctional land use is *diversity*, representing 'the different land use functions that can simultaneously be found in the project area at hand'. These can simply be counted as frequencies according to the definitions of land use functions as presented in Section 2:

$$Diversity = \frac{Actual\ number\ of\ functions}{Maximum\ number\ of\ feasible\ functions}$$

The actual number of functions in our case cannot exceed 9; the theoretically maximum number of feasible functions. This means that the maximum value of diversity is always 1. This indicator is very tentative, but could be made more precise by identifying and assessing sub-functions.

An indicator that is closely related to diversity is dispersion. This indicator is based on the Herfindahl-Hirschman index (HHI) (see Hannan, 1997, and Lijesen et al. 2002) and dependent on the actual number of functions as used for the diversity indicator. Dispersion measures 'the degree to which each function is present in equal proportions within the project area (in m^2 land use)', as represented by the following formula:

$$Dispersion = \frac{1}{I * \sum_{i=1}^{I} (M_i/S)^2}$$

in which:
M_i = the amount of m^2 land used by a single function i (input)
S = the total amount of m^2 land use of the project area
I = the actual number of functions (were I has a maximum of 9 (according to the definition of land use functions in Section 2)).

This indicator has a maximum value of 1, indicating that there is maximum dispersion within the project area, or. in other words, the proportion of each individual function is equal to that of the other functions. The minimum value of this indicator varies with the number of functions that are present within the project area. Acwrding to our maximum of 9 land use functions as defined is this paper, the minimum dispersion value will be 1/9. This indicator will, ideally, be measured in m^2 land use, since this shows the proportion of territories of land used within the project area by the different functions, and with that, the spatial dispersion of the functions in a flat surface.

The second element in the definition in the definition of multifunctional land use is *interweaving*, which is defined as 'the degree to which different functions touch upon other functions'. This case of interrelatedness can be represented by the following formula:

$$Interweaving = \sum_{i=1}^{I} \frac{B_i}{S}$$

in which:
B_i = the length of physical boundaries with other functions within the project area
S = the total amount of m^2 land use of the project area
I = the actual number of functions (where I has a maximum of 9 (according to the definition of land use functions in Section 2)).

This indicator does not reckon with the third (vertical) dimension yet and can therefore only ba measured in a flat surface. To solve this shortcoming, the surface of boundaries between land use functions could be measured for B_i, and S could then be expressed in m^3. However, these are just tentative ideas that have not been crystallised yet, but this will be done in future studies.

Another relevant feature is concerned with intensity of functions. Although *intensification - as a* process - in itself is difficult to observe in a static sense, it is useful and illustrative to show the land use intensity for different land use alternatives. Therefore, it will be used here as one of the indicators representing the degree of multifunctionality of a specific land use project. Only in the case of a comparison between different altematives we may draw conclusions about the degree of multifunctional land use (possibly related to the third dimension). Intensification should, in first instance, be measured for each single land use function (i = 1, , I), which can be represented by the following formula:

$$Intensification = \frac{Q_i}{M_i}$$

in which:
Q_i = the amount of non-land input of a certain land use function (houses, employment, etc)
M_i = the amount of m^2 land used by a single function i (input)
I = the actual number of functions (where I has a maximum of 9 (acwrding to the definition of land use functions in Section 2)).

Intensification may also be measured for the project area as a whole:

$$Intensification = \sum_{i=1}^{I} \frac{Q_i}{S}$$

in which:
Q_i = the amount of non-land input of the project area
S = the total amount of m^2 land use of the project area
I = the actual number of functions (where I has a maximum of 9 (according to the definition of land use functions in Section 2)).

In this case, in measuring the intensiftcation for the project area as a whole we need to have a common unit of measurement to express the non-land inputs of the different land use functions. For example, in the first indicator for intensification, the input for working and business and amenities is measured via the number of jobs created, and the input for residential housing is measured via the number of houses to be realised. These units cannot be summed up and should therefore be expressed in a common unit of measurement. An example of such a unit is to express all non-land inputs in Euro (€).

For future studies, it will be interesting and necessary to analyse the ceteris paribus influence of the aggregation level of the land use functions on the indicators.

In the next section, an example of a multifunctional land use project will be analysed in terms of 'degree of multifunctionality'. The aforementioned criteria will be applied to the different altematives for developing the so-called South-Axis ('Zuid-As') in Amsterdam.

7. *The Amsterdam South-Axis*

The Amsterdam South-Axis ('Zuid-As') is in general regarded as a location with a high development potential for offices, houses and amenities. It is intended to become a location with an adequate mix of functions, which should not have a negatie effect on the functioning of the city centre of Amsterdam. The development of the South-Axis is intended to create a new urban environment with its own identity. There are a number of goals for the development of the South-Axis, in particular: to eliminate the barrier effect of the ring road around Amsterdam, to prevent monofunctionality. and to create a solid and consistent public space. With the South-Axis project, this part of the city is intended to undergo enormous improvements in quality. Currently, there is already a certain mix of functions available at the South-Axis. There are housing areas of high quality on both sides of the ring road, as well as an intemational exhibition centre and conference facilities (RAI), the World Trace Centre, a university (Free University) and an academic hospital, the Court of Justice and various office buildings. The Masterplan South-Axis aims at strengthening this mix of functions in order to increase the status of the location as an office location.

In the planning process thus far three alternatives for the development of the South-Axis are distinguished: the Dock altemative, the Dike alternative, and the Combination alternative. These alternatives will be compared with a reference situation, assuming an autonomous development of the area (DRO, 1998).
The *Dock alternative* puts all infrastructure underground over a length of 1.2 kilometre, providing a huge extra amount of available building space.
In the *Dike alternative*, all through traffic will be guided on an elevated dike infrastructure. The latter will be situated at the current level on a broadened dike body of 170 m wide. This alternative has a compact terminal for public transport with short transfer distances, the external architecture of the dike is on a qualitatively sophisticated level, and there is an extra underpass for slow traffic.
The *Combination alternative* combines different aspects of the Dock and the Dike alternative. The essence of this alternative is that only parts of the infrastructure will be brought underground: road traffic will be positioned underground, whereas the rail infrastructure will stay at its current level. In this alternative, the dike will become narrower, allowing for construction of offices and houses on both sides of the dike on top of the road infrastructure (that has been constructed underground).
Table 1 shows the number of m^2 floor space occupied by certain functions as well as the number of planned jobs and houses within the project area.

Table 1 The three alternatives for the Amsterdam South-Axis ('Zuid-As') and autonomous development in m^2

	Autonomous	Dock	Dike	Combi
Total built-up area	962300	2362300	1467000	2004800
Offices	461700 (48%)	984600 (42%)	790200 (54%)	1063900 (53%)
Residential housing	334700 (35%)	1056000 (45%)	466900 (33%)	717200 (36%)
Amenities	165700 (17%)	321700 (13%)	209900 (14%)	223700 (11%)
Infrastructure	1374091	1423031	1374091	1397454
Green	309153	370328	309153	335190
Water	80000	100000	120000	90000
Remaining	827626	562926	787626	723921
Planned jobs	24800	35000	40500	53100
Planned houses	2880	8450	3730	5730

With the data in this table we can try to calculate the indicators as developed in Section 8 (see Table 2).
The first indicator is diversity. The value of this indicator is for all four altematives the same: namely, 1; there are seven land use functions (offices, residential housing, amenities, infrastructure, water, natura and landscape, and remaining) out of seven possible. feasible functions (according to the definitions used in Section 2). Agriculture is nota feasible land use function at the Amsterdam South-Axis.
The second indicator, dispenion, is more difficult to calculate. The only alternative for which all necessary data are readily available is the Dock altemative. For the other alternatives, the data for the Dock alternative have been adapted to the characteristics of the alternative concemed. This means that with the help of a land use map for the Dock alternative, the proportions of land that will be lost by applying the Combi alternative, Dike alternative or Autonomous development (in which only a part of the layer on top of the infrastructure wilt be realised (Combi alternative) or no extra layer at all (Dike alternative and Autonomous development)) are attributed to the respective land use functions. Furthermore, as a result of a lack of data, the dispersion has been calculated by means of the amount of m^2 floor space instead of

land use, for the individual land use functions as well as the total project area. The result shows that the Dock alternative has the highest value for dispersion. A value of one would mean that all functions occupy the same share of the project area. Therefore, its value of 0.71 means that, of all alternatives, the land use by the different land use functions in the Dock alternative is most evenly spread.
Also, the calculation of interweaving creates some difficulties. There are no data available on the length of physical boundaries with other functions within the project area for any of the four alternatives. This means that this indicator can only be judged qualitatively. However, since there Is no information on the distribution of the functions over the project area (to which extent will the functions be realised In a flat surface or will the third dimension be used), nothing can be said about the qualitative value of this indicator either.
The final indicator of intensification cannot be calculated for each single land use function, since there are no detailed data on land use per function. However, the second indicator for intensiftcation as presented in Section 6 can be calculated. but only for work and business, residential housing, and amenities. It shows some differences between the alternatives as a result of differences in the number of planned jobs and houses in the project area. Since the distribution of m^2 floor space for houses, offices and amenities differs per alternative as well, the values for intensification for offices, houses, and amenities can best be considered in combination.
Another calculation that could be made with the available data and that is illustrative for intensification is the amount of m^2 floor space created for work and business, residential housing, and amenities divided by the amount of m^2 floor space of the total project area, and by the land used for these functions (variants on floor space index (FSI)). These values show which alternative creates the biggest amount of m^2 floor space within the project area, and which alternative uses the area for offices, housing and amenities most intensively. It is not surprising that the Dock alternative has the highest value on the first indicator, since it has more space available to built offices, houses and amenities, due to bringing the infrastructure underground. However, for the second indicator, the highest value can be found in the Combi alternative. This shows that in this altemative, the buildings will have to be higher in order to create the planned floor space within the planned area. This alternative uses the land for offices, houses and amenities most intensively, which is also reflected in the value for intensification on offices (Q_i/S).

Table 2 Indicator values for the four altematives for the Amsterdam South-Axis ('Zuid-As')

		Autonomous	Dock	Dike	Combi
Diversity		1	1	1	1
Dispersion		0.60	0.71	0.67	0.69
Interweaving		n.a.	n.a.	n.a.	n.a.
Intensification:					
1) Q_i/S	Offices	0.009	0.013	0.015	0.019
	Residential housing	0.001	0.003	0.001	0.002
	Amenities	0.001	0.001	0.001	0.001
2) Floor space created /total project area		0.35	0.85	0.53	0.72
3) Floor space created / total 'commercial land use		4.97	7.20	7.57	0.42

We have distinguished in an illustrative case study four development alternatives, each characterised by distinct numerical indicators which may be seen as quantitative approximations of attributes of these plan altematives. This is a clear case of a multi-criteria evaluation problem, which aims to identify the most promising choice possibilities. The four alternatives have been evaluated by means of the so-called Regime analysis, which is a discrete multi-criteria method (Hinloopen et al., 1953; Nijkamp et al., 1990). This method is based upon two kinds of input data: an impact matrix and a set of politica1 weights. The impact matrix shows the effect of each altemative on the indicators consldered. The set of weights provides information about the relative importance of the indicators considered. In this analysis no policy weights have been given to the indicators, so we used a uniform weight factor. On the basis of these inputs, the Regime method provides us with a ranking of the altematives in terms of multifunctionality (see Table 3).

Table 3 Performance scores of altematives based on Regime analysis

Alternative	Score
Autonomous	0.00
Dock	0.82
Dike	0.35
Combi	0.83

This table shows that the Combi altemative has the highest score on multifunctionality, although the difference with the Dock alternative is negligibly low. The Dike alternative has a much lower score, whereas the Autonomous development shows the lowest score. A sensitivity analysis attributing different weights to different indicators gives no really different results. Depending on the indicator that will be attributed the highest score, the Combi alternative or the Dock altemative has the highest score. The Autonomous development always has a score of 0, whereas the Dike alternative always has an intermediate score.

Table 3 shows furthermore that - given the current available database - the Combi and the Dock alternative are obvious examples of alternatives with a high multifunctionality value. The two others are inferior and do not offer a clear contribution to multifunctionality. It should be added that multifunctionality in itself is not a policy goal. It serves merely to realise other objectives, such as a keen management of scarce space. In our particular case, both the Dock and the Combi option reduce the barrier function of the infrastructure and may therefore be attractive policy options, while the multiiunctionality is just the instrument through which this objective is met.

These results show that bringing the infrastructure underground creates favourable opportunities for multifunctional land use. The choice for the Dock altemative as the most optimal filling in of the project area, however, is mainly based on the increase in connectivity between the different areas of Amsterdam, which, in this alternative, will no longer be separated by the infrastructure. The importance of infrastructure for the Amsterdam South Axis is recognised and travellers are best facilitated in the Combi and Dock alternative.

8. Concluding remarks

The concept of multifunctional land use has turned out to be a very interesting one in urban and infrastructure planning. Economic research has traditionally put great interest in mainly monofunctional land use based on issues of efficiency and (more recently) sustainability. Multifunctional land use, however, attempts to combine several socio-economie functions in the same area, so as to conserve scarce space and to exploit economies of synergy. Clearly, multifunctional land use shows several relations with monofunctional land use, but is, nevertheless, different in that, from a project perspective, projects can only be considered more multifunctional or less multifunctional. In order to operationalise the concept of multifunctional land use, a functional typology of specific land use functions is needed, along with the development of criteria and indicators to measure the degree of multitünctionality of specifc land use projects. From a critical analysis of common definitions of multifunctional land use, the most important elements for measuring the degree of multifunctionality became clear. Applying these indicators to a case study (the Amsterdam South-Axis) showed that different project alternatives might have different degrees of multifunctionality. It is interesting to analyse this in further detail in the light of underlying assumptions regarding the ultimate choice for one of the alternatives. Another future challenge is to adjust the current indicators for a comparison between different projects, instead of an analysis of different alternatives for one project as presented in this paper. Therefore, a reflection on the nature of indicators conceming factors such as aggregation level of land use functions, dispersion, concentration, diversity, interweaving and intensity, taking into account the state of affairs in other disciplines, is likely to be a very interesting exercise.

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